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Persistence and Structural Change in the Technological Specialization of Brazil

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Introduction

Since the beginning of the nineties, Brazil has been going through a process of trade liberalization. The effects of this process have not been fully under analysis. Most of the literature that deals with this issue has a macroeconomic approach, especially those that concern the trade balance and its fiscal and monetary consequences and the impacts these features have on the growth process. The assessment of the microeconomic consequences of the growth process, apart from being scarce, are limited to studies on the competitiveness of industrial structures, on the productive re-structuring and on consequences over the structure of domestic markets.

Trade liberalization may however have deeper consequences on structural transformation than those that have been under investigation and may have effects on the productive specialization of the country (Myro and Alvarez 2003) and particularly on technological competences. A country's technological competences are closely related to its productive and commercial base. Productive transformations may therefore affect the technological structure of a country.

This paper aims to investigate changes in the technological specialization of Brazil and to draw a profile of its technological competences before and after the trade liberalization. The paper is organized in four sections apart this introduction and the final conclusions. In the first section, the paper presents a survey of the literature on the determinants of a country's technological specialization and the consequences trade liberalization may have on the allocation of technological efforts across technical fields. The second section describes the database. The third section is dedicated to the analysis of the Brazilian technological specialization through the undertaking of three analyses:

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(1) the changes in the revealed technological advantages (RTA) as indicator of the technological opportunity; (2) the relative position of Brazil with respect to three groups of countries (leaders, Asian followers and Latin-American followers); and (3) a shift-share analysis of the components of the technological structural change.

1 TECHNOLOGICAL SPECIALIZATION AND STRUCTURAL CHANGE

The domestic technological specialization (DTS) may be defined as a measure of the regularity of a country's technological activity in each technical field it is active with respect to a set of technologies and to its relative position in comparison to other countries (Archibugi and Pianta 1992:119, Malerba and Montobbio 2003). The origins of DTS may be found in the determinants of the rhythm and direction of technical change across technical classes or classes of technology, that is, the technological regimes composed by technological opportunity, appropriability and demand characteristics.

Appropriability conditions emerge from the public nature of knowledge. The use of different modes to appropriate knowledge is closely connected to the knowledge base of a sector and to the type of information in use, to the value technology has to those that possess it and to the distinct forms in which technical change occurs. The use of appropriability mechanisms and their effectiveness vary across industries but tend to be stable over time, due to the fact that the nature of their changes responds to regulatory and institutional imperatives.

Technological opportunity has a strong sectoral dimension and its dynamism is strongly constrained by changes in techno-scientific paradigms. The opening o windows of opportunity associate with the emergence of new micro-paradigms in the international scenario may conduct to the recovery of technological competences that added to the pervasive effect of technology may reinforce and rearrange DTS.

Demand-pull theories hold that changes in the demand of goods and services are the main driving forces of technical change. Their arguments rely on the influence these forces have on investment patterns. From demand-pull theories emerges the third determinant of technological regimes. Demand may motivate innovative entrepreneurial activity in two respects: market size and price-elasticity of demand

(Cohen 1995: 214). Though market size does not directly affect the level of investment on innovation, it affects the expected profitability of R&D disbursements, which tends to be a function of market size for the innovation. For the same market size, innovation incentives tend to be greater the greater the expected growth rate. R&D expenditures tend also to improve with market size the lower the demand elasticity, including when the expenditures associated with the development of technologies increase (Dasgupta and Stiglitz 1980). The relation between R&D and market size reduces for industries and R&D types where innovations are easily commercialized and where the expectation of rapid growth derived from the introduction of an innovation is greater.

Price-elasticity affects directly the marginal benefit of the investment in R&D (Kamien and Schwartz 1970). This may distinguish between process and product innovation. The greater the elasticity of demand with respect to price the greater the incentives for process innovation will be. Whenever demand is inelastic, the incentives for product innovation will be greater and lower the incentive for process innovation. Dasgupta and Stiglitz (1980) argue also that, for higher levels of price-elasticity, the growth in the costs of innovation will take to lower sectoral and firm-level R&D expenditures; and for inelastic demand, R&D expenditures of an industry with free entry will be greater than the optimum level of R&D expenditures and duplication of R&D efforts may take place. A final technological attribute of demand are user characteristics, such as the level of sophistication of users and the influence on the type of technology being generated by suppliers (Mansfield 1973: 205-205). In this way, the diversity and direction of the innovative process is also driven by users, due to the specificity of production and market.

Under all these established considerations, trade liberalization may play a strong role and influence the structure on both the supply and demand determinants of technological efforts. From the demand perspective, trade liberalization may conduct to the appearance of new markets and the expansion of the existing markets. This may originate increase in the market size and in the expectation of growth of these markets. These changes may lead to a reallocation of R&D resources to the technologies connected to markets where the expected profitability of the R&D expenditures is greater. The other demand dimensions may also affect changes in the structure of technological specialization if trade liberalization and changes in productive specialization alter demand price-elasticity of output or if it modifies user requirements.

Furthermore, international trade theories forecast that trade liberalization and other processes of economic integration are capable to reorganize the national productive structure and to modify national technical base. The building of technological strengths is strongly connected to the nature of the production processes of scientific and technical knowledge and to the specificities that these processes assume in each country, with respect to its technical and productive base. Thus, there is a set of factors that determine DTS by the supply side: (i) the structure of innovative activity that defines the trends for technological development under the influence of a previously determined technical base and of the specific modes of the innovative process; (ii) the persistence and heterogeneity of innovative activities at the firm-level; (iii) the linkages between knowledge and technologies (spillovers); and (iv) national systems of innovation and technological policies.

The Technical Base

The *technical base* is determined by the endowments of scientists and engineers, by the allocation of resources to R&D in different technical fields and by the modes of knowledge accumulation specific to each country (external and foreign technology acquisition, scientific and technological policies, interaction amongst agents involved in the production of public knowledge). The productive base is defined by the specialization pattern of each country (high, medium and low technology sectors) and by the integration among its productive base. The technical base depends on the productive structure. Each industry develops its own modes of knowledge production and accumulation, according to the needs and technological imperatives of its knowledge base (Pavitt 1984). For instance, science-based sectors rely more on science advances than supply dominated sectors and tend to carry out important R&D efforts, while production intensive sectors tend to develop close user-producer interactions and learning by doing efforts have greater importance.

Thus, a country’s core technological competences are associated with its productive and commercial advantages. The structure of innovative activity in each sector includes, moreover, elements connected to the market structure of its leading industries, such as market concentration, firm size, entry conditions, the degree of technological collaboration amongst agents, factors that are positively linked to the DTS (Malerba e Montobbio 2003). Further technological development of a country’s competences depends on specific characteristics of their previously accumulated technical and productive base. Thus, the development of DTS assumes a path dependent characteristic and tend to be stable over time.

Persistence

The idiosyncratic character of the process of knowledge accumulation and of technology trajectories may lead to the creation of particular advantages associated with specific technologies, constraining a country's specialization to areas that are close to previously developed technologies. This phenomenon characterizes the innovative persistence of a country's trajectory or, in other words, to a conditional probability that the innovating agents or technologies in period t will be repeated in period t+1. In the presence of persistence, the innovation may be considered as a purely random process, not controlled by the action of firms. Persistence is present as a result of the accumulative nature of learning and of the organizational and technological capabilities that are specific to firms. Persistence is related to the qualitative heterogeneity of innovation agents, which develop and dominate different capabilities to innovate. As a consequence, processes of accumulation of technology reproduce past capabilities and past asymmetry amongst agents, generating further heterogeneity through time (Malerba et al, 1997).

Malerba et al. (1997) show that: (i) technological advantages are greatest in sectors characterized by the action of large companies that constantly perform innovations and that are highly competitive; (ii) persistence and asymmetry are phenomena that affect the patterns of innovation across countries and sectors. This process may generate concentration and stability in the ranking of innovative performance and low turbulence (entry and exit) amongst the population of innovating agents. Patel and Pavitt (1991) find evidence on the similarity of large firms' technological advantages across time and on the relation between these advantages and their home countries' own technological advantages. Under this perspective, DTS would be strongly and positively correlated to the stability of the rankings of innovating agents and countries and negatively correlated to the rate of turbulence.

Another interpretation about the role played by previously accumulated technological competences at the firm level is originated in the Schumpeterian view that the building of advantages is a result of competition for market position, which would indicate the turbulence on the rank of innovators. This type of behavior should be more frequent in the initial stages of a new technological paradigm. Malerba et al. (1997) shows empirical evidence in favor that DTS has a higher correlation to *creative accumulation* than to *creative destruction*, although some elements of the latter process may in some cases influence DTS.

Spillovers

Knowledge linkages across technologies may also play an important role in the establishment of DTS. Linkages across technologies and the technology flows across agents develop spillovers that can influence the innovative performance of other agents that carry out activities in different, though closely associated technical fields inside the same country. Malerba and Montobbio (2003) show evidence that for the cases of USA, UK, France, Italy and Germany, persistence of DTS holds for 135 technology classes related to Chemistry, Electronics and Machinery and that technology flows, concentration of innovators, the entry of new innovators and technological cooperation are positively correlated to persistence.

National Systems of Innovation

National systems of innovation are referred to differences registered in the skills of labor force, to the development of scientific knowledge by Universities and public research labs, to the relations amongst agents (users, producers, government) and to the articulation and priorities of technological policies in the carrying out of R&D and other scientific efforts. The empirical effort collected from the experience of the 80's revealed a tendency for the specialization of technological profiles of technological leaders and for some European followers in such a way that differences in the specialization of countries increased across time (Archibugi and Pianta, 1992, 1994). Recent work show that large countries are more likely to distribute their innovating activities in a wide spectrum of technologies and that the mobility across technological classes are very high when technological classes are sufficiently disaggregated. The same evidence shows a large level of asymmetry across countries. This may be reflecting the fact that it is easier to increase specialization in areas where there is previous technological advantage than in areas where there is low technological advantage (Mancusi 2001). These findings weaken the position of theories that hold technological accumulation and path dependence as explicative factors for persistence through time.

2 THE DATABASE

This paper uses data from the Espace Bulletin Database of the European Patent Office (EPO). The database consists of patents that have been filed and authorized by EPO from 1978 to 2005. Patents have been widely used as an indicator of technological competences at firm, industry and country levels, due to its homogeneity, long period series and the information it contains about technical fields where they have been filed. This is information is obtained through the International Patent Classification (IPC) and allows for international comparison of technical fields. Moreover, EPO's patent applications have a further quality, they are in most cases a second or a third patent application and therefore the knowledge contained in the patent has been evaluated before by another patent office and, most importantly, its use has been demonstrated of some value to the firm, institution or individual that filed it before (Grupp and Schomach, 1999:385). Finally, EPO's registration costs are quite large when compared to other databases and therefore, it constitutes a quite tight filter for the quality of the patent, whenever international comparisons are made.

However, there are some shortcomings in the database. Agents will patent at EPO only if they access or wish to access the European market. Otherwise, they may lack interest in patent at EPO. Furthermore, firms with greater internationalization of their R&D activities will be more likely to patent at EPO. As a consequence, EPO's level of internationalization of R&D activities tends to be greater than other patent databases. For instance, identifying the location of R&D efforts by the country of residence of the inventor, Patel (1995) finds a level of internationalization of 7.8% for 250 US firms, for the 1985-90 period. Using the same indicator, Cantwell (1995) finds a level of 6.8% of internationalization of R&D for US firms in the 1969-90 period. Rocha and Urraca (2002) using EPO database for the 1978-1999 period find a level of internationalization of 21.8% for 116 US firms.

3 STRUCTURAL CHANGE AND SPECIALIZATION OF BRAZIL IN THE POST-LIBERALIZATION REFORMS PERIOD

The assessment of the occurrence of structural change and shift of technological specialization in Brazil will be carried out through three exercises: (i) the elaboration of a revealed technological advantage (RTA) indicator by country and technical field, controlled by the level of opportunity of each technical field; (ii) an analysis of the relative position of the technological structure of Brazil in comparison with three groups of countries (leaders, Latin American followers and Asian followers, see table 1) in the period before and after trade liberalization in Brazil; and (iii) a shift-share analysis that will examine the nature of the structural change.

Following the literature on patents (Patel 1995, Cantwell 1995 and Rocha and Urraca 2002), a country's technological activity has been identified by the country of residence of the inventor registered in the patent. Whenever inventors residing in more than one country were found, double counting was performed. The technological structure of each country has been measured by the distribution of the number of patents per technical field. IPC was divided into 22 technical classes in order to assess a country's technological profile. Table 1 shows the total number of patents for each country used in the paper. Though the number of patents for some countries is quite small, one can see that each group of countries has a quite homogeneous patenting activity when normalized by the number of inhabitants. Some countries, such as China and India, have a quite atypical behavior when compared to their regional peers.

Table 1 Number of Patents, Rate of Growth of the Number of Patents and Number of Patents per Number of Inhabitants, per Selected Countries

	Number of Patents		Rate of Growth	Number of Patents per million inhabitants	
	78-90	91-05	78-80/91-05	1990	2000
BRAZIL	278	1303	368.7	1.9	7.6
Leaders					
USA	123216	337372	173.8	492.9	1224.9
JAPAN	71772	213823	197.9	581	1684.7
GERMANY	102711	236325	130.1	1294.2	2876.1
FRANCE	40788	89006	118.2	702.9	1472.8
UK	35292	66902	89.6	613.1	1119.6
NETHERLANDS	13058	34451	163.8	873.6	2164
Latin American Followers					
ARGENTINA	84	483	475	2.6	13

CHILE	20	126	530	1.5	8.3
COLOMBIA	30	72	140	0.9	1.7
MEXICO	99	511	416.2	1.2	5.3
VENEZUELA	34	140	311.8	1.7	5.8
Asian Followers					
CHINA	188	3082	1539.4	0.2	2.4
KOREA	206	13211	6313.1	4.8	279.5
HONG KONG	190	608	220	33.3	89.5
ÍNDIA	205	1968	860	0.2	1.9
SINGAPORE	101	1556	1440.6	33.1	387.3
TAIWAN	510	3360	558.8	25.2	154.3*

(*): population of Taiwan is refered to 1998.

Source: EPO, Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.1, Center for International Comparisons at the University of Pennsylvania (CICUP), October 2002, and own elaboration.

Though leader countries have a greater innovative activity, the database shows that followers have catch-up with them. Latin American followers have however shown a weaker performance when compared to Asian countries. In the Latin American case, Chile and Argentina have shown the best performance in terms of growth, followed by Mexico and Brazil. In the case of Asia, South Korea has grown its patenting activity the faster, followed by China and Singapore.

3.1 Change and Persistence in Technological Specialization (RTA)

The technological specialization is measured through the RTA indicator. This indicator allows the detection of the technological strengths of each country, that is, the technical classes where the share of patents is higher than world's average share, that is, the ratio of the share of a country's patents in a particular technical field to the share of total database's patents in that technical field. Whenever RTA rates over one it is said that the country has specialization in that technical field. The rate of change of RTA between two fields is an indicator of change of technological structure.

Table 2 shows the rate of change of RTA for the 22 technical fields under analysis for each country that compose our database. Technical fields are classified according to the level of *dynamism* of the technological opportunity. A technical field is considered *dynamic* whenever the share of that technical field in the overall database increases over time. Whenever the rate of change of the technical field is negative (decrease in the share of patents), the technical field is considered as *stagnated*.

The two first columns of table 2 shows that the most dynamic technical fields are not necessarily the ones with largest share of patents, that is, the dynamism of a technical field is not correlated by its relative importance in comparison with other technical fields. The dynamism of technological opportunity indicates the technical fields where *windows of opportunity* have emerged across time. Some sectors with small shares of total patenting show quite high dynamism, such as Biochemistry, Paper and Pulp, Motors and Pumps, Printing and Personal and Domestic appliances. Sectors of large shares of patenting that are considered dynamic are Electronics, Health and Amusement, Instruments and Transportations.

In order to assess the level of mobility and persistence, we identified the number of technical fields where a country had specialization at the initial time period, C_i, the number of technical fields where a country had specialization at the final period, C_f, and the number of technical fields where countries had specialization in both periods, C_{if}. Two indicators were then composed: (i) a persistence index, $IP ? \frac{C_{if}}{C_t}$, and (ii) a mobility index, $IM ? 1 ? IP$, where $C_t ? C_i ? C_f$, that is, the total number of fields where there was specialization in both periods. Both indexes vary between 0 and 1. If IP is equal to 1, IM will be 0, meaning that all technical fields where the country registered specialization in the initial period coincide with technical fields where the country registered specialization in the final period. If IP values 0 and IM values 1, the opposite is true, that is, none of the technical fields where the country registered specialization in the initial period coincide with those technical fields where the country was specialized in the final period.

Table 2 shows that Latin American countries had mobility indexes much higher than leading countries and Asian followers. Moreover, their rates of growth in specialization were also higher than these other groups. Very low persistence indexes were found for Argentine, Chile, Colombia and Venezuela and a bit higher for Mexico and Brazil. Latin American countries maintained their specialization in technical fields where they traditionally hold comparative advantage such as Health and Agriculture, in the general case. Brazil maintained specialization in Biochemistry, Motors and Pumps, Drilling and Mining, Textiles or Flexible Materials and Oil and Carbon Chemistry

Table 2 Rate of Change of RTA of Dynamic and Stagnated Technical Fields by Country, sorted by the Dynamism of the Technological Opportunity of the Technical Field

	Increase in Shares	OT 78-05	Argentina	Brazil	Chile	Colômbia	México	Venezuela	US	Japan	Germany	France	UK	Holanda	China	Hong Kong	India	Singapore	South Korea	Taiwan
Dynamic Technical Fields																				
Electronics	94,50	**8,11**	16,2	-52,3			-40,2	-75,0	6,2	**-14,8**	-28,5	**-18,6**	5,2	**-3,1**	127,9	-1,6		167,8	**115,6**	7,1
Biochemistry	63,44	2,76		**9,2**			**-63,4**		**8,7**	**-46,7**	8,8	18,7	**35,6**	40,4	**-11,0**		**-38,7**	201,8	**-54,9**	57,9
Health and Amusement	51,29	**8,41**	**-20,1**	**-11,4**		**51,5**	**-41,2**	**-42,2**	**13,8**	-27,6	-14,2	26,8	**10,8**	-3,6	-15,3	-50,4	**47,1**	-27,9	**-59,9**	-17,9
Paper and Pulp	13,63	0,48		747,9			**-14,8**		-11,0	-3,7	**32,6**	-24,1	-18,5	-18,8	**-81,2**		**-72,5**		-79,2	
Motors and Pumps	10,65	2,72	**-16,2**	**-26,1**	**-89,2**		92,6	**-78,1**	-11,0	**9,1**	**30,8**	-13,9	-10,2	-45,4	**-77,4**	-71,8	3,6	-58,9	-30,6	-32,8
Instruments	9,88	**17,61**	-39,6	-36,0			146,8	-26,3	**-3,9**	**-10,6**	1,9	-4,4	3,6	17,1	7,2	**-27,3**	132,3	24,7	126,0	56,1
Printing	6,02	1,88		-59,6			**-54,3**	**-77,1**	-12,0	**26,5**	-20,0	-10,3	0,0	13,8	3,6	121,1		89,8	16,6	**-50,8**
Personal and Domestic Appliances	5,41	2,86	197,0	32,0			**-44,9**	-53,9	-3,0	-5,7	-9,3	**6,3**	0,2	8,3	**9,9**	**46,0**	18,6	**-69,2**	**-69,5**	**-23,5**
Transportation	1,74	**8,01**	113,7	18,6		-100,0	-4,8	19,4	-6,9	15,5	**28,3**	**3,3**	**-24,8**	-9,8	-49,3	16,7	-46,2	-56,3	-66,1	-31,1
Stagnated Technical Fields																				
Electricity	-0,75	**9,13**	22,7	91,8		**-79,0**	121,2	-2,1	-13,2	**12,3**	2,1	-12,7	-19,9	**-18,6**	39,5	**-48,4**	-43,3	**14,3**	**-1,5**	59,8
Building	-12,89	2,78	-20,1	-1,7		-4,3	-55,5	**-90,7**	-3,9	-3,5	**30,2**	**-8,2**	**1,7**	**-23,5**	334,1	7,6		**-62,7**	-42,9	**-38,8**
Separation and Mixing	-13,11	3,16		**-32,6**	**46,1**	-4,1	56,1		-2,4	3,0	**8,4**	**21,2**	9,2	-10,1	26,4	259,6	**-37,1**	-67,6	144,6	-53,4
Lighting and Heating	-13,86	2,05	**-39,4**	119,6			169,9		-7,8	39,5	14,8	-12,1	-15,0	-5,2	95,9	33,0	-63,7	-24,6	121,6	**16,7**
Food and Tobacco	-15,46	1,14	**-10,9**	710,5			404,2	**-71,3**	**-19,7**	-2,2	14,4	-2,4	17,5	**25,0**	181,4	343,6		145,7	-26,4	-53,3
Machinery	-18,68	**5,30**	-41,2	10,6	**-80,5**	105,0	352,7	**-30,3**	-1,9	11,1	**17,5**	-11,2	-26,4	-18,5	-23,7	121,0	19,6	17,1	113,0	**-29,2**
Agriculture	-18,92	1,45	**-53,5**	**-1,9**	**-2,1**	**19,9**	-4,4		22,4	35,5	1,3	**-2,3**	**-10,8**	**23,0**	-17,2	2,8		**-88,0**	-61,8	27,3
Metallurgy	-20,17	1,62	**-45,5**	**-71,9**	**59,1**	**-100,0**	**-23,2**		-22,2	**-2,1**	-5,9	-20,6	-34,8	-36,3	**-73,6**	56,6	-25,0	-10,6	211,6	-27,8
Enginnering	-23,57	3,97	423,4	98,9	**-86,2**		69,0	-36,4	-21,3	36,9	**35,9**	**-6,8**	-15,6	-13,7	**9,9**		36,3	-76,2	-30,3	40,4
Drilling and Mining	-26,82	0,46	**-76,2**	**40,5**			**-100,0**	**43,8**	**9,7**	-22,9	-17,2	-19,9	**64,1**	149,4	-91,7	**-100,0**		-86,7	-91,4	
Textiles and Flexible Materials	-29,32	1,43	121,4	**31,3**	**-100,0**		-81,7		10,9	-9,5	**7,8**	-1,8	-3,4	-22,6	25,1		**-61,7**		91,6	77,9
Organic and Inorganic Chemistry	-31,81	**14,06**	**-29,5**	17,8	388,8	**-67,1**	62,6	78,1	**-0,4**	0,3	**-7,7**	28,8	22,3	2,8	-1,9	-8,3	**-8,7**	-22,4	**-44,5**	84,9
Oil and Carbon Chemistry	-42,41	0,60	**-39,6**	**-7,1**	**-100,0**		**-66,4**	**51,8**	**-9,7**	39,9	-22,7	41,1	91,6	**-13,3**	**-22,3**		207,5	**12,7**	-53,5	-38,5
Persistence Index			0,286	0,467	0,214	0,167	0,417	0,231	0,750	0,857	1,000	0,857	0,667	0,833	0,667	0,500	0,500	0,222	0,250	0,667
Mobility Index			0,714	0,533	0,786	0,833	0,583	0,769	0.250	0,143	0,000	0,143	0,333	0,167	0,333	0,500	0,500	0,778	0,750	0,333

Note: Blue indicates persistence, yellow, new specialization in the technical field, and red, loss of specialization in the technical field.

These countries directed their specialization to some technical fields of high dynamism as Biochemistry, in the general case, Paper and Pulp, in the cases of Brazil, Chile, Colombia and Mexico, Personal and Domestic Appliances, for every country except Venezuela and Transportation for Brazil and Argentina. The movement into these technical fields engaged these countries in windows of opportunity that helped in the increase of their shares in the world's total patenting. However, they also moved towards sectors that showed to be stagnated. These are the cases of Lighting and Heating for Brazil and Mexico; Food and Tobacco for Brazil, Chile and Mexico; Engineering for Brazil and Argentina; Textiles and Flexible Materials for Argentina and Colombia; and Organic and Inorganic Chemistry for Chile, Mexico and Venezuela.

On the other hand, some specializations were abandoned. Amongst the abandoned technical fields some had great *dynamism*, which means technical fields where these countries have lost windows of opportunity. This can be seen in the cases of Chile and Venezuela for Motors and Bombs and Mexico and Venezuela for Printing. However, for Latin American countries, the loss of specialization is more often verified in *stagnated* technical fields. Argentina, Brazil and Colombia abandoned their specialization in Metallurgy, Brazil in Separation and Mixing, Argentina and Mexico in Drilling and Mining, Chile and Mexico in Textiles in Flexible Materials, Argentina and Colombia in Organic and Inorganic Chemistry and Argentina, Chile and Mexico in Chemistry of Oil and Carbon.

The main characteristic of Brazil is the engagement in windows of opportunity that arose during the beginning of the nineties. In the previous period, Brazil was specialized in three of the nine dynamic technical fields. During this period, it maintained its specialization in the dynamic technical fields and became specialized in other three dynamic technical fields. However, it did not become specialized in those technical fields that hold the greatest shares of patenting, with the exception of Transportation. Moreover, it reduced its already low share in Electronics and Instruments.

The dynamism of Brazil is also reflected in stagnated technical fields. In the initial period, the country was specialized in six out of thirteen technical fields of low dynamism. At the end of the period, Brazil was still specialized in four of these six technical fields, loosing specialization in Separation and Mixing and Metallurgy. However, it gained specialization in Lighting and Heating, Food and Tobacco and Engineering.

All together, Brazil revealed a high level of innovating dynamism that lead it to diversify its technical base and to enjoy windows of opportunity. However, it was not able to enjoy the most important windows of opportunity as it remained not specialized in Electronics, Electricity, Machinery and Instruments.

The leading countries show slower rates of change in their technological opportunities, and most importantly show a very high level of persistence of their technological specialization. The persistence index assumes value 1 for Germany and lower than one for the remaining set of leading countries. This feature indicates that the previous accumulation of knowledge has a strong influence on the direction of technical change and also reveals consolidated domestic technological advantages in leading countries. On the other hand, these countries appear to be less likely to engage in new windows of opportunity that emerged during the years under analysis. Furthermore, these countries show a greater stickiness of their technological bases and therefore they show greater rigidity in leaving or de-specializing in declining technical fields. Very few cases of mobility were observed. For instance US has lost specialization in Food and Tobacco and Agriculture, Japan has left Biochemistry, UK, Engineering and the Netherlands, Electricity. UK also gained specialization in Food and Tobacco, and in Chemistry of Oil and Carbon.

Leaders show also an important difference when compared to Latin-American followers: their specialization occurs in technical fields that have large shares of overall patenting, therefore, they hold competences that are core to the overall technical base. This is true for both the dynamic (Japan, France and the Netherlands in Electronics; Germany, France and UK, in Transportation, US and Japan in Instruments, and US and UK in Health) and the stagnated technologies (Japan in Electricity; Germany in Machinery and US and Germany in Chemistry Organic and Inorganic).

The group of Asian followers presents very high rates of change in the specialization indexes. They registered highest rates of mobility when compared to leaders, though inferior to those registered by Latin American countries. The lowest persistence indexes amongst these countries are Singapore and South Korea. Hong Kong and India had intermediate levels of persistence (around 0.5) and China and Taiwan had IP over 0.6. Persistence is related to technological and productive advantages that have been traditional in these countries. Examples are South Korea in Electronics and Electricit; China, Hong Kong and Taiwan in Personal and Domestic Appliances and China in Chemistry of Oil and Carbon. The mobility across technical fields had greater association with the exit of technical fields than with the entering into new technical fields of specialization. This feature lead to a concentration and consolidation of each countries' technological specialization, though these countries were unable to enter into windows of opportunity. However, these countries did exit technical fields that showed to be stagnated.

A second analysis of persistence and structural change of a country's technological specialization is the examination of the role played by the country's technological activity in the final result of its specialization. Table 3 assesses this issue through the correlation of the country's initial and final specialization to the country's patenting share in each technical field. Archibugi and Pianta (1992:83) argue that the correlation coefficient measures how close a country's technological specialization is to the distribution of the rate of growth of its patenting shares. The correlation made over its final pattern of specialization indicates if the trend taken by the country's innovative activity determines its specialization. The correlation over its initial pattern specialization indicates the level of determinism (persistence) of the technical change.

Table 3 shows that the final pattern of specialization is positively correlated to the rate of growth of patenting in each technical field. Germany, UK and in some measure Brazil, Asian followers and the Netherlands show quite high levels of correlation of RTA_F to P_{ij} (column 1). The persistence hypothesis on the other hand seems to have been rejected. Only Germany shows a significant coefficient in column 3. In some countries the coefficient is negative, that is, the initial pattern of specialization is negatively correlated to the rate of growth in each technical field.

Table 3 Correlation Coefficients between the Revealed Technolgical Advantage and Rates of Growth of Patenting Activity

	RTA_F vs P_{ij} (1)	RTA_F vs N_{ij} (2)	RTA_I vs P_{ij} (3)	RTA_Ivs N_{ij} (4)
Brazil	0.68	0.72	-0.32	-0.32
Leaders				
US	0.36	0.36	0.03	0.16
Japan	0.19	0.37	-0.20	0.30
Germany	0.83	0.15	0.44	-0.16
France	0.22	-0.07	-0.36	-0.28
UK	0.88	0.35	0.27	0.01
Holanda	0.51	0.30	0.07	-0.01
Latin America*	0.11	-0.02	-0.19	-0.17
Asian followers**				
(except South Korea)	0.55	0.60	-0.20	-0.10
South Korea	0.51	0.68	-0.46	-0.28

Source: Own elaboration.

Notes: RTA_F – Revealed Technological Advantage at the Final Period

RTA_I – Revealed Technological Advantage at the Initial Period

P_{ij} – Rate of growth of the share of patenting of country j in technical field i.

N_{ij} – Number of patents of technical field i, filed by country j.

* Includes Argentina, Chile, Colombia, Mexico and Venezuela.

** Includes China, Hong-Kong, Índia, Taiwan and Singapore.

3.2 Change in the Relative Position of Brazil between periods (1978-90 and 1991-2005)

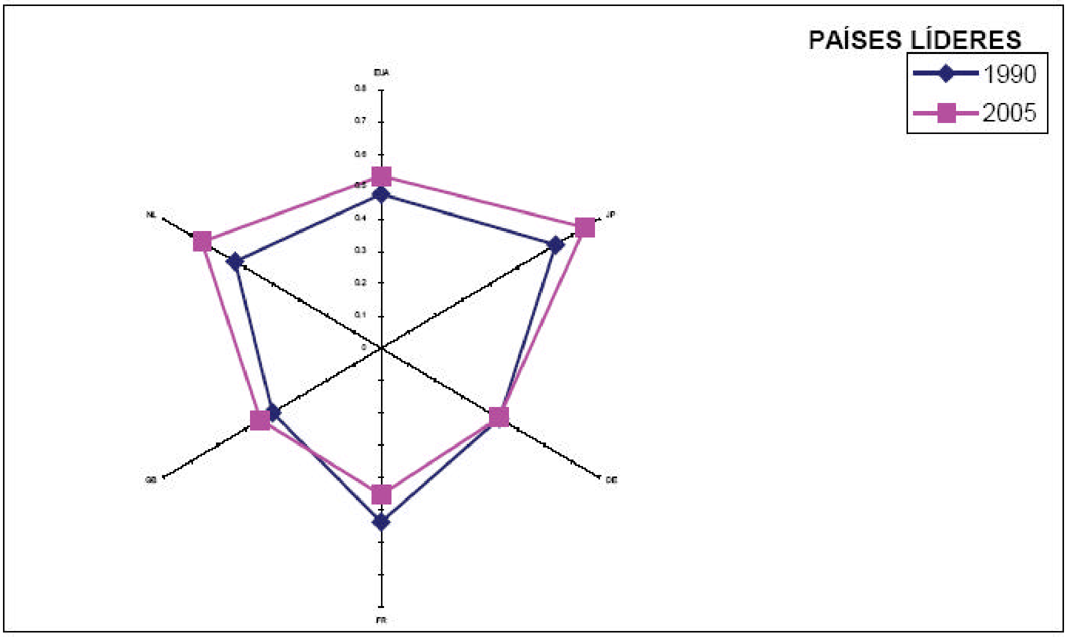
The position of Brazil in relation to other countries before and after the trade liberalization process may be determined by the similarity index, suggested by Myro and Alvarez (2003). This index assesses the similarity of the distribution of competences in relation to other countries. The index is defined by:

$$IS ? \underset{i}{?} \left| s_{ij} ? s_{ik} \right|$$

where s_{ij} is the share of the technical field i in country j and s_{ik} represents the same for country k. The index is valued between 0 and 2. The closer it is to 0, the greater the similarity of the technological structures will be, the closer it is to 2, the greater the dissimilarity of the technological structures. Indexes were run for 22 technical fields in two moments in time: the pre-trade liberalization period (1978-1990) and the post-trade liberalization period (1991-2005). Graphs I, II and III present the results.

Graph I shows the evolution of the similarity index (IS) of Brazil in comparison with leading countries. Brazil seems to have increased the distance of its technological structure in comparison with leading countries. Brazil reduced the distance with respect to France and maintained with respect to Germany. The distance to US, Japan and UK increases between the periods, with great emphasis with respect to Japan. Furthermore, Brazil appears to have increased its distance to leading countries that had greater distances in the initial period.

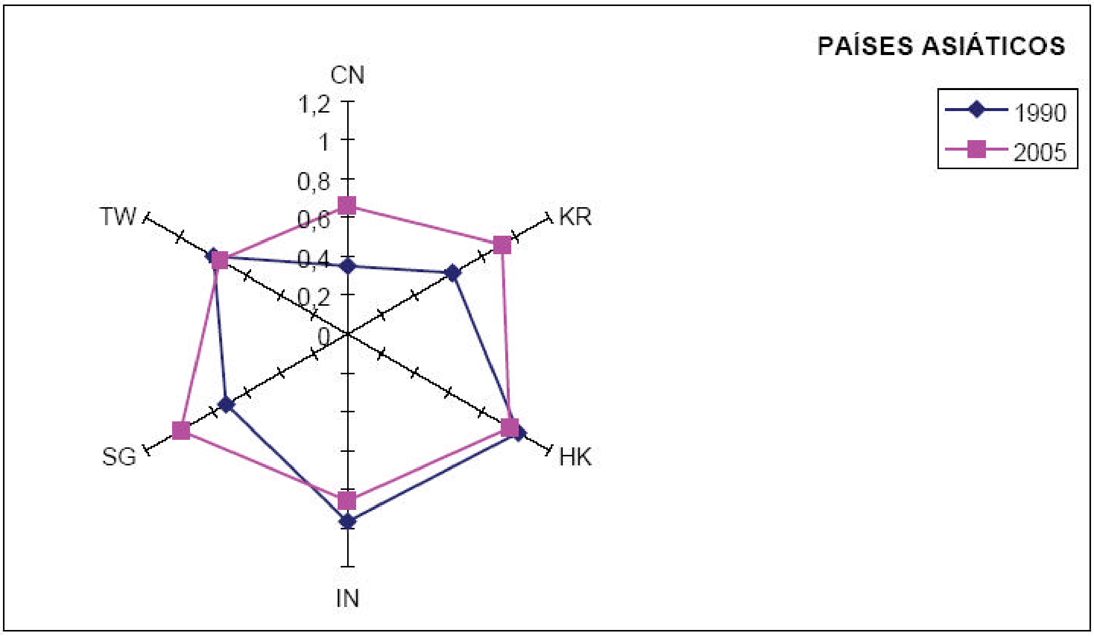
Graph I Evolution of the Similarity Index of the Brazilian Technological Struture to the Technological Structure of Leading Countries



Source: EPO e elaboração própria.

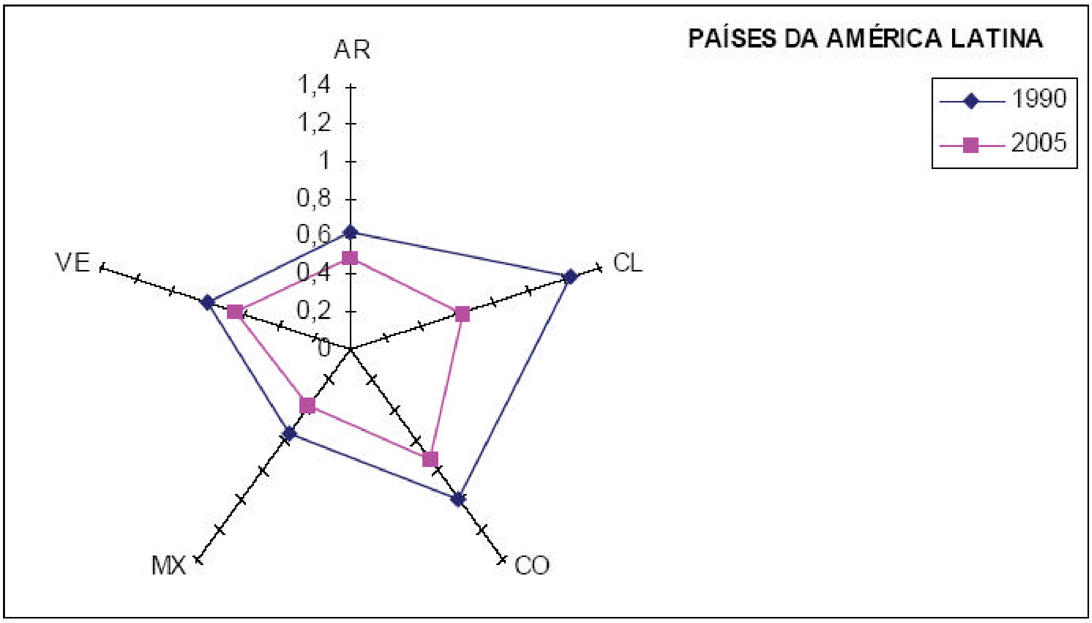
Differences between the Brazilian technological structure and Asian followers in the post-trade liberalization period are larger than those in the pre-trade liberalization period. Registered IS indexes are close to one for India and Hong Kong, 0.8, for Taiwan, between 0.6 and 0.8 for Singapore and 0.4 for South Korea. Contrary to what was observed for leading countries, in the case of the Asian followers, countries that were initially closer to Brazil were the ones which registered the greater distance enhancements.

Graph II Evolution of the Similarity Index of the Brazilian Technological Struture to the Technological Structure of Asian Followers



These changes suggest that: (i) Brazil had a homogeneous distance pattern across Asian followers; (ii) Brazil had a different experience in respect to technological development when compared to Asian followers, with emphasis to those countries that registered a greater dynamism and were successful in catching-up to leaders.

Graph III Evolution of the Similarity Index of the Brazilian Technological Struture to the Technological Structure of Latin American Followers



Changes with respect to Latin America followed a different pattern. In the pre-trade liberalization period, Brazil had great similarity to Mexico and Argentina, respectively 0.4 and 0.6 and had greater dissimilarity with Chile, Colombia and Venezuela, respectively, 1.2, 0.7 and 0.8. Nonetheless, in the post-trade liberalization period, Brazil reduced its differences to these countries. Te greater reductions were registered with respect to Chile, Colombia and Venezuela. Therefore, the technological structure of Brazil became closer to its neighbors. Furthermore, differences to Latin American followers became the smallest amongst the three country groups.

Changes in the technological structure in Brazil were associated with a specialization pattern that is characteristic of Latin America, based in technologies related to the natural resources based industries and to labor intensive activities. Therefore, technological structural change in Brazil is likely to increase the distance to other development patterns such as knowledge intensive and pervasive technologies, which are more likely to be representative of the development of leaders (Urraca 2007).

3.3 Structural Decomposition of Technological Growth

The application of shift-share analyses may help in the understanding of structural change. In the particular case of technologies, the starting point is the increase in the patent share of a country between two periods. Structural decomposition allows the knowledge on the origin of the growth according to the following effects (Laursen 1999):

(i) *technological share effect* – measures whether a country is gaining or losing shares of world patents;

(ii) structural technology effect – measures the role of the location of the country, that is, whether a country is gaining share due to its *initial* location according to the 22 technical fields under analysis. Countries may be located in technical fields of overall rapid or slow growth and enjoy the advantages or disadvantages of this specialization; and

(iii) technology adaptation effect – measures the effect of the country's *active movements* towards rapid or slow growth technologies. This effect may be decomposed into two further effects:

   a. The *technology growth adaptation effect* will be positive if a country moves towards rapid growth technical fields, that is, if it enjoys windows of opportunity, and negative if it leaves these fields.

   b. The *technology stagnation adaptation effect* will be positive if the country enters stagnated technical fields and negative, otherwise.

Let *t-1* denote the initial period and *t*, the final period, Δ, the variation between the two periods and P_{ij}, the total patents filed by country *j* in technical field *i*, and define:

$p_j = \frac{\sum_i P_{ij}}{\sum_i \sum_j P_{ij}}$ as the share of patents country *j* in the world's total patenting;

$p_{ij} = \frac{P_{ij}}{\sum_j P_{ij}}$ as the share of patents country *j* holds on technical field *i* in the world's total patenting in technical field *i*;

$o_i = \frac{\sum_j P_{ij}}{\sum_i \sum_j P_{ij}}$ as the share of technical field *i* in the world's total patenting

So that:

$$\Delta p_j =$$

$$\underbrace{\sum_i (\Delta p_{ij} o_i^{t-1})}_{\text{technology share effect}} + \underbrace{\sum_i (p_{ij}^{t-1} \Delta o_i)}_{\text{structural technology effect}} + \underbrace{\sum_i (\Delta p_{ij}(\Delta o_i + |\Delta o_i|)/2)}_{\text{technology adaptation growth effect}} + \underbrace{\sum_i (\Delta p_{ij}(\Delta o_i - |\Delta o_i|)/2)}_{\text{technology adaptation stagnation effect}}$$

As the rate of growth of patenting activity may measure technological opportunity the three last terms of the above equation represent a measure of the access a country has over the technological opportunity. If the structural technology effect of a country is positive and high, this may mean the country had a *"right" initial technological specialization,* and, as a consequence, the positive role of persistence on the country's specialization. If the two latter effects are positive, this means that the country *moved* towards the *"right"* technological specialization, that is, it moved towards technical field with high technological opportunity and left technical fields of low technological opportunity.

Table 4 presents the results of this decomposition for the countries and development level groups. Brazil registered a strong growth in its patenting share between the two periods (80%). This growth was due to the technological share effect, that is, the dynamism of its innovating activity. Brazil's initial specialization did not contribute to this growth, on the contrary, it had a negative effect. This means that Brazil had a *"wrong"* initial specialization. Brazil did enjoy some windows of opportunity and the technology growth adaptation effect shows a positive sign. This means that there was some innovating activity that moved Brazil to the *"right"* specialization. However, this effort was more than compensated by the abandonment of important windows of opportunity that lead Brazil to the *"wrong"* technological specialization as it is shown by the sign of the technology stagnation adaptation effect, that is, Brazil left technical fields of rapid growth. On average, Brazil became specialized in slow growth technical fields.

In the group of leaders, one may find two patterns. On the one hand, US, Japan and the Netherlands increased their shares in total patenting, while Germany, France and UK had a decrease of their patenting share. The good performance of the first group may be explained by both the technological share effect and the structural technology effect, specially in the case of Japan. In this group, the adaptation effect has an overall negative sign for Japan and the Netherlands and a positive sign for the US. In all cases, the technology stagnation effect was negative.

Table 4 Decomposition of the Growth of Patenting Share

	Share 78-90 (%)	Share 91-05 (%)	Total Effect (%)	Technological Share Effect	Structural Technology Effect	Technology Growth Adaptation Effect	Technology Stagnation Adaptation Effect
Brazil	0.062	0.112	82.02	91.062	-1.055	5.444	-13.433
Leading Countries							
US	27.277	29.108	6.71	3.625	1.597	1.848	-0.358
Japan	15.889	18.449	16.11	15.457	3.487	-0.696	-2.138
Germany	22.738	20.390	-10.33	-5.755	-3.398	-2.128	0.955
France	9.030	7.679	-14.95	-14.329	0.423	-1.840	0.793
UK	7.813	5.772	-26.12	-25.994	-0.121	-2.189	2.186
The Netherlands	2.891	2.972	2.82	1.104	1.152	0.678	-0.109
Latin America*	0.059	0.115	94.43	98.496	0.808	8.915	-13.787
Asian Followers** (except South Korea)	0.264	0.912	202.91	239.840	-0.666	33.461	-27.485
South Korea	0.046	1.140	2375.40	2153.447	2.593	402.298	-182.937

* Includes Argentina, Chile, Colombia, Mexico and Venezuela.

** Includes China, Hong-Kong, Índia, Taiwan and Singapore.

The technological share effect was the most important cause of the poor performance of the second group of leading countries. Only in the case of Germany the initial specialization had a negative sign and the adaptation effect as a whole had a negative performance. In this case, the incapacity to engage in technical fields with high dynamism (windows of opportunity) played a key role. The countries did however leave technical fields of low dynamism.

Latin American countries had a positive growth of their shares. This growth was due to the technology share effect. The structural technology effect though positive played a minor role. These countries were able to engage into new windows of opportunity. This is represented by the positive effect of the technology growth adaptation effect. However, this growth was more than compensated by the negative sign of the technology stagnation effect, showing that these countries became stronger in technologies with low technological opportunities.

Finally, the group of Asian followers was characterized by very high rates of growth of their patenting shares, especially in the South Korean case. These rates of growth were due to a very high level of technological dynamism represented by the technological share effect. The group of Asian followers that excludes South Korea had a negative sign for the structural technology effect. However, this effect played a minor role. In the case of South Korea, this effect is positive. In both cases, however, the overall sign of the adaptation effect is positive, due to the technology growth adaptation effect, though the technology stagnation adaptation effect had a negative sign. Therefore, one may say that these countries moved into the right technical fields.

4 CONCLUSIONS

This paper aimed at analyzing the process of structural technological change in Brazil in the pre and post-trade liberalization periods with respect to three groups of countries (technological leaders, Asian followers and Latin American followers. The paper showed that Brazil went through a structural change in its pattern of specialization, though some persistence was identified. This persistence was related to revealed technological advantages in technologies (Health and Amusement, Agriculture, Motors and Pumps, Drilling and Mining and Chemistry of Oil and Carbon) that are related to productive sectors where Brazil as shown over years to be particularly strong. Brazil was able to diversify its technical base. However, the overall direction of this diversification is not very well defined. It engaged in some windows of opportunity such as Paper and Pulp and Transportation, but entered into technical fields of low level of dynamism such as Lighting and Heating, Food and Tobacco and Engineering. Brazil wasn't able however to occupy a strong position in technical fields that have a greater representation in terms of share of patenting in EPO's database. It kept its specialization in niche technologies. On the other hand the exit of stagnated technical fields was compensated by the entering in other stagnated technical fields.

When comparing its technological profile to other countries, Brazil seems to become more similar to its Latin-American neighbors and dissimilar to Asian followers and world leaders. This is reflected by the increase in the distance to South Korea, China and Singapore and to the closer relation to Chile's technological profile.

The shift-share analysis reveals that the increase in the share of patenting was due to the dynamism of the inventive activity in Brazil, due to the technological share effect. Structural technology effect had a negative, though almost insignificant effect. However, the country showed that it became increasingly specialized in technical fields of slow growth, the technology adaptation effect, that is, it cannot count on the *right* specialization in order to increase its patenting share. In this sense, the hypotheses on the effect of technological accumulation on persistence and the role played by spillovers across technologies are confirmed, for the entry as innovator I some technical fields requires previous competences in related technology. The obstacles faced by Brazil in entering in technical fields such as Electronics and Instruments, for instance, may be explained by the importance of technology accumulation.

Finally, there was some evidence on the importance of persistence across countries. Technological leaders showed a greater effect of persistence in their patterns of specialization. The same performance was not identified by the two groups of followers. Therefore, the effect of technological accumulation seems to be greater amongst leaders, showing that their competences represent strengths, as pointed out by Malerba et al. (1997). Persistence reproduces the heterogeneity between leaders and followers. Followers are more likely to show strong movements across technical fields (greater turbulence) in search for consolidation of their technological strengths.

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